

# EPA Guidelines

## Site contamination —acid sulfate soil materials

Issued November 2007

*EPA 638/07: This guideline has been prepared to provide information to those involved in activities that may disturb acid sulfate soil materials (including soil, sediment and rock), the identification of these materials and measures for environmental management.*

### What are acid sulfate soil materials?

Acid sulfate soil materials is the term applied to soils, sediment or rock in the environment that contain elevated concentrations of metal sulfides (principally pyrite  $\text{FeS}_2$  or monosulfides in the form of iron sulfide  $\text{FeS}$ ), which generate acidic conditions when exposed to oxygen.

Identified impacts from this acidity cause minerals in soils to dissolve and liberate soluble and colloidal aluminium and iron, which may potentially impact on human health and the environment, and may also result in damage to infrastructure constructed on acid sulfate soil materials. Drainage of peaty acid sulfate soil material also results in the substantial production of the greenhouse gases carbon dioxide ( $\text{CO}_2$ ) and nitrous oxide ( $\text{N}_2\text{O}$ ).

The oxidation of metal sulfides is a function of natural weathering processes. This process is slow however, and, generally, weathering alone does not pose an environmental concern. The rate of acid generation is increased greatly through human activities which expose large amounts of soil to air (eg via excavation processes). This is most commonly associated with (but not necessarily confined to) mining activities.

Soil horizons that contain sulfides are called 'sulfidic materials' (Isbell 1996; Soil Survey Staff 2003) and can be environmentally damaging if exposed to air by disturbance. Exposure results in the oxidation of pyrite. This process transforms sulfidic material to sulfuric material when, on oxidation, the material develops a pH 4 or less (Isbell 1996; Soil Survey Staff 2003). Acid sulfate soil materials include **potential acid sulfate soil material** (sulfidic material) and/or **actual acid sulfate soil material** (sulfuric material), both of which can occur in the same soil profile.

## Potential acid sulfate soil material (PASSM or sulfidic material)

Potential acid sulfate soil material is material that has not been exposed to air or undergone oxidation and consequently is composed mostly of accumulations of iron sulfide minerals, one of the end products of the *sulfate reduction* process. Sulfur occurs in the environment in several oxidation states, as elemental sulfur (S), in an oxidised state (S<sup>+6</sup>) and in a reduced state (S<sup>-2</sup>). Several organic and mineral forms of reduced sulfur occur in wetland sediments, but two forms of iron sulfide minerals are of special interest from an environmental point of view: pyrite (FeS<sub>2</sub>) and iron sulfide (FeS).

Soil and sediment materials rich in iron sulfide (black ooze) tend to be very dark and soft. Iron sulfides can react rapidly when they are disturbed (ie exposed to oxygen). Pyrite will tend to occur as more discrete crystals in soil and organic matter matrices and will react more slowly when disturbed. The oxidation of iron sulfide in potential acid sulfate soil material (sulfidic material) results in the formation of actual acid sulfate soil material or sulfuric material.

## Actual acid sulfate soil material (AASSM or sulfuric material)

These soils or sediments contain highly acidic soil layers (sulfuric material) caused by aeration of sulfidic material rich in iron sulfides. Sulfuric material is composed either of mineral or organic soil material (15 cm or more thick) that has a pH <3.5 and can usually be identified by the presence of bright yellow jarosite mottles or streaks.

## Application of guideline

This guideline should be used to assess the risks associated with the occurrence of acid sulfate soil material where the following may occur:

- excavation or disturbance of acid sulfate soils, such as construction of roads, drainage works, foundations, flood mitigation works, dams and ponds for aquaculture projects, sand or gravel extraction and dredging. Consideration needs to be given to the excavation site and the appropriate disposal for the excavated material
- dewatering or lowering of the water level, such as, drainage works or deepening of existing drains, dewatering of dams, wetlands, ponds and dredging works
- use of acid sulfate soils, such as in the construction of pond walls, dams, flood mitigation works, importation of fill material, and reclamation or foreshore works
- mosquito control works associated with the drainage of surface water.

These examples are not exhaustive and there may be other situations where this guideline should be considered. Generally, any proposal to disturb soils or interfere with the watertable where potential acid sulfate soil materials or actual acid sulfate soil materials exist, should consider this guideline.

## Regulatory framework

The *Environment Protection Act 1993* (the Act) has substantial penalties for causing environmental harm to air, land, surface water and groundwater. These penalties can apply to individuals, companies and to its directors. The maximum penalty for serious environmental harm for a corporation is a fine of up to \$2,000,000, and for a person, a fine to a maximum of \$500,000 or four years imprisonment or both, where the harm was caused intentionally or recklessly and with the knowledge that the environmental harm will or might result.

In addition to the penalties for causing environmental harm, all people are required to observe their general environmental duty<sup>1</sup>. The general environmental duty requires that 'a person must not undertake an activity that pollutes, or might pollute, the environment unless the person takes all reasonable and practicable measure to prevent or minimise any resulting environmental harm'.

A person undertaking an activity that has the potential to cause environmental harm must comply with the provisions of the Act and relevant Environment Protection Policies (EPPs).

### Compliance and enforcement

Further information on compliance and enforcement may be found in the document *EPA Guidelines for Compliance and Enforcement* (2006), available from the EPA (tel 08 8204 2004) or from the EPA website at <[www.epa.sa.gov.au/pdfs/guide\\_compliance.pdf](http://www.epa.sa.gov.au/pdfs/guide_compliance.pdf)>.

### Occurrence of acid sulfate soil materials

Most acid sulfate soil materials were formed by natural processes during the Holocene geological age (the last 10,000 years). They were originally deposited in marine, estuarine or river settings and occur predominantly in low-lying areas near the coast, such as coastal floodplains, rivers and creeks, deltas, coastal flats, back swamps and mangrove areas.

Metal sulfides can be found in many rock types, generally at low concentrations, from which the risk of environmental impact due to acid generation is low. The risk of significant environmental impact occurs where metal sulfides are concentrated as a result of igneous, metamorphic and/or pedogenic processes.

Elevated sulfide concentrations are often associated with mineral deposits, including coal, precious metals (eg gold, silver, platinum), base metals (eg copper, lead, tin, zinc) and uranium. As a consequence, acid generation from mine wastes is a significant environmental issue for the mining industry.

### Occurrence of actual or potential acid sulfate materials in South Australia

In Australia, coastal acid sulfate soils occupy an estimated 95,000 km<sup>2</sup>, of which 74,000 km<sup>2</sup> are exposed at some point during the tidal cycle. This area contains well over two billion tonnes of potentially dangerous sulfidic material (Fitzpatrick *et al* 2006). These soils underlie coastal estuaries and tidal flats close to major population centres. In South Australia, actual and potential coastal acid sulfate soils occupy approximately 2,410 km<sup>2</sup> (Fitzpatrick *et al* 2006) and have an estimated acid reservoir of two million tonnes.

In South Australia, metal sulfides have been associated with historical mining of copper, gold and silver/lead deposits and within sediments throughout the state. Metal sulfides are also associated with some of South Australia's coal deposits.

The CSIRO has undertaken studies on the distribution and properties of acid sulfide soil materials in South Australia (Merry *et al* 2003; Thomas *et al* 2003) and the locations on the coastal management maps can be viewed at <[www.atlas.sa.gov.au](http://www.atlas.sa.gov.au)>. More recently, acid sulfate soils have been mapped in South Australia as part of a national mapping program to develop a unified *Atlas of Australian Acid Sulfate Soils*. This atlas contains a detailed legend of consistent national classification and terminology (Fitzpatrick *et al* 2006). The information was collated and assembled using all published acid sulfate soils, land systems, marine habitat, elevation (DEM), tidal, estuarine, climate, vegetation and remotely sensed data from

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<sup>1</sup> Section 25, *Environment Protection Act 1993*

GIS. This map base is viewable as part of the Atlas of Australian Acid Sulfate Soils and published as a web-served GIS at the Australian Soil Resource Information System (ASRIS) site <[www.asris.csiro.au](http://www.asris.csiro.au)>.

## Impacts of acid sulfate materials

Acid sulfate soil materials can affect land use, development and amenity of the surrounding environment. Therefore management of acid sulfate soil materials has to be considered during the planning stage of any project, prior to land clearance, drainage or construction, where these materials are likely to be found.

Acid sulfate soil material can have an impact on the following:

- Engineering and landscaping works:
  - sulfuric acid generation can result in the corrosion of concrete, steel and some aluminium alloys used in buildings, drainage systems and roads
  - the use of acid sulfate soil material as site fill material or in embankments can affect plant growth and block pipe drainage systems due to the formation of iron oxides.
- Agricultural practices:
  - both acidity and increased liberation of soluble metals may result in direct plant toxicity and decreased uptake availability of some nutrients, as well as a potential reduction in farm productivity
  - acid sulfate soil materials may also result in a decrease in animal productivity via a decrease in pasture quality and an increased uptake of aluminium and iron by grazing animals.
- Fish and aquatic life:
  - acidic waters entering estuarine, coastal or riverine environments can result in mortality of fish and crustaceans and can affect aquatic plants through direct acid exposure, smothering of aquatic plants by iron precipitates and toxicity by aluminium and heavy metals.
- Local amenity:
  - the presence of acid sulfate soil materials produces an offensive odour, predominantly due to 'rotten egg gas' (hydrogen sulfide H<sub>2</sub>S).

The potential environmental impact of acid sulfate soil material depends on a number of factors, including:

- exposure to oxidising conditions potential acid sulfate soils materials will not generate acidic discharge unless exposed to oxygen and water
- the nature and extent of the sulfidic characteristics of the material these characteristics can vary widely and will affect both the amount and concentrations of acidic discharge and the rate of generation
- the capacity for self-neutralisation acidic discharge may be neutralised, depending on the amount and type of neutralising material available in the soil
- the buffering capacity of the receiving environment acidic discharge may be neutralised by the presence of organic material, limestone or dolomite and the buffering effects of some water in the receiving environment.

These factors determine the environmental risk posed by acid sulfate soil material and should be assessed on a case-by-case basis.

## Identification of acid sulfate soil materials

When assessing the potential for a site to contain acid sulfate soil material, reference should be made to the South Australia Acid Sulfate Soil Map prepared by the CSIRO <[www.atlas.sa.gov.au](http://www.atlas.sa.gov.au)> or the recently developed Atlas of Australian Acid Sulfate Soils at <[www.asris.csiro.au](http://www.asris.csiro.au)>.

Field inspections of soil and water should be undertaken by a suitably qualified and experienced environmental consultant to provide an initial indication of the presence of acid sulfate soil materials (see <[www.epa.sa.gov.au/pdfs/guide\\_sc\\_consultant.pdf](http://www.epa.sa.gov.au/pdfs/guide_sc_consultant.pdf)>). Indicators of acid sulfate soil conditions for soil and groundwater are included in Appendix A. Groundwater pH and the soluble chloride/soluble sulfate ratio are other useful indicators of acid sulfate conditions. Geological information and visual inspection for presence of sulfides can also be used to assist in the identification of acid sulfate rock.

According to Soil Taxonomy (Soil Survey Staff 2003), sulfidic material applies to soil or sediment layers with a pH of >3.5, which if incubated as a layer one-cm thick under moist conditions (field capacity) while maintaining contact with the air at room temperature, show a drop in pH of more than 0.5 to a pH value of 4 or less within eight weeks.

If one or more of the indicators are observed during the inspection, additional investigations should be undertaken to confirm whether acid sulfate soils (actual or potential) are present.

Before development in coastal areas can take place, the developer must first undertake the following:

- assess the risk associated with acid sulfate soil material disturbance through a thorough acid sulfate soil material investigation
- prepare a long-term acid sulfate soil material management plan
- conduct a field trial of remediation techniques at the site
- develop contingency plans in case of complications

(Ahern *et al* 1998; 2000)

Successful management of acid sulfate soil material depends on the results of the acid sulfate soil material investigation. Results from the investigation determine the most appropriate management strategies for a site.

Such an investigation would need to provide information on:

- the environmental setting
- location of and depth to acid sulfate soil material
- existing and potential acidity present in the soil profile
- soil characteristics.

Consequently, CSIRO have developed the following staged approach (Figure 1), to assist consultants to develop acid sulfate soil material risk assessments particularly in coastal environments.

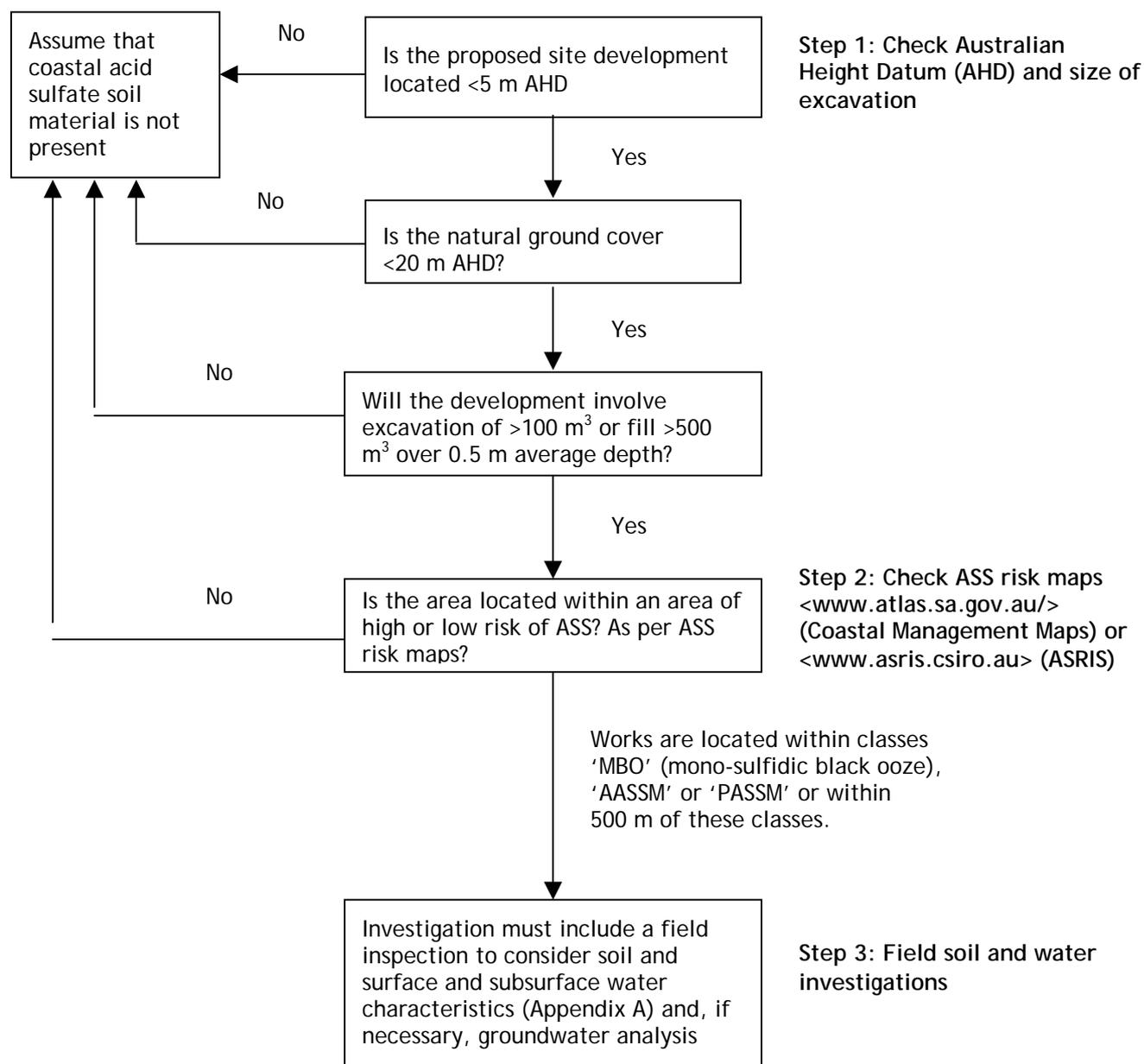


Figure 1 Identification of acid sulfate soil materials

## Assessment of acid sulfate soils

Following confirmation that the field indicators and tests have identified the potential occurrence of acid sulfate soil materials (Appendix A), a detailed sampling and analysis program should be undertaken to assess the extent and characteristics of the soils. Laboratory methods for the determination of acid sulfate soil properties are included in Appendix B.

A suitably qualified and experienced environmental consultant should undertake the field and laboratory assessment and classification of acid sulfate soil materials (see [www.epa.sa.gov.au/pdfs/guide\\_sc\\_consultant.pdf](http://www.epa.sa.gov.au/pdfs/guide_sc_consultant.pdf)).

When determining the sampling density for the assessment of acid sulfate soil materials, reference should be made to Schedule B2 of the *National Environment Protection (Assessment of Site Contamination) Measure* (1999) and *Australian Standards AS 4482.1*. It is important to ensure that a representative selection of samples is obtained to enable a sufficient level of assurance that both the material and extent of acid sulfate soil materials have been adequately assessed.

In addition to the determination of acid sulfate soil material properties, an assessment may also be undertaken for contamination by metals and other wastes, depending on previous site activities and land uses. Acid sulfate soil materials that are contaminated with metals or other pollutants should be managed to ensure there is no risk to human health and the environment.

## Classification of acid sulfate soil materials

The analytical methods and assessment criteria for determining whether soils and rocks have the potential to generate acid are provided in Appendices B and C respectively. Separate criteria apply to soils and rocks and if any of the criteria are exceeded, the material can be classified as acid sulfate soil or rock, as appropriate.

The clay content of soil has a major influence on the amount of sulfuric acid generated after disturbance. Soils with high clay content generally have a higher natural pH buffering capacity and can neutralise more acid than soils with low clay content. Therefore the amount of oxidisable sulfur in the soil that needs to be managed varies with the clay content of the soil. Particle size analysis should be undertaken to determine the clay content of the soil to ensure the appropriate criteria are used.

## Management measures

Where acid sulfate soil materials (actual or potential) are present on a site, the EPA recommends that, where practicable, the material should not be disturbed.

Sites that contain acid sulfate soil materials need to be managed to avoid adverse environmental impact and risk to human health.

If the preliminary assessment has established the presence of actual or potential acid sulfate soil materials, consideration will need to be given to appropriate management measures to mitigate potential impacts.

Where disturbance of the acid sulfate soil material is unavoidable, the main objective of acid sulfate soil material management is to prevent or minimise the potential for on- and off-site impacts, using the most cost-effective and environmentally sustainable methods. The suitability of management measures will depend on the nature and location of the acid sulfate soil materials.

## Common management approaches

### 1 Determine presence of acid sulfate soil materials

Characterise proposed development sites for acid sulfate properties, taking into account this guideline.

### 2 Minimise disturbance or drainage of acid sulfate soil materials

It may be appropriate to select an alternative non-acid sulfate soil site rather than undertake remediation of impacts caused by disturbance of acid sulfate soil materials. If an alternative

site is not feasible, works can be designed to minimise the need for excavation or disturbance of acid sulfate soil materials by:

- undertaking shallow excavations and drainage measures
- avoiding lowering of groundwater levels that may result in exposure of soils
- covering the surface with clean soil if acid sulfate soil materials are close to the surface.

### **3 Prevent oxidation**

This may include staging the project to prevent oxidation and placing potential acid sulfate soil materials into an anaerobic environment, usually below the watertable.

### **4 Minimise oxidation rate and isolate higher risk materials from exposure**

This may include covering with soil or water to reduce oxygen availability and control of water movement, or controlling bacteria or other limiting factors (eg alkalinity) by either physical or chemical means to reduce the oxidation rate.

### **5 Contain and treat acid drainage to minimise risk of significant off-site impacts**

Typically, this would involve installing a leachate collection and treatment system.

### **6 Provide an agent to neutralise acid as it is produced**

This would involve mixing the acid sulfate soil material with an excess of lime.

### **7 Separate acid sulfate soil material**

This may include use of mechanical separation, such as sluicing or hydrocyclone to separate acid sulfate fines from non-acidic sulfate material, followed by treatment or disposal of acid sulfate fines in an anaerobic environment.

### **8 Hasten oxidation and collection and treatment of acid sulfate leachate**

This involves spreading the acid sulfate soil material in a thin layer over an impermeable area to achieve a high level of oxidation. Rainfall or irrigation leaches the soil and the leachate is then collected and treated.

### **9 Manage stockpiled materials**

Stockpiled acid sulfate soil material needs to be managed to ensure no adverse environmental impacts occur. This should include:

- minimising the quantity and duration of storage
- minimising the surface area that can be oxidised
- covering the soil to minimise infiltration
- stormwater control measures
- controlling erosion and collection/treatment of runoff.

### **Other management approaches**

Innovative management measures should be trialled on a small scale. On-site treatment and management of acid sulfate soil material is preferable to off-site disposal. Disposal of acid sulfate soil to marine spoil grounds is unlikely to be approved by the EPA.

## Remediation options

Basic principles of acid sulfate soil material remediation are to:

- avoid or minimise disturbing sulfidic materials
- contain acidic leachate within soil profile using barriers
- neutralise acidity and at the same time manage the movement/discharge of toxic oxidation products
- dilute acidic leachate before discharging into the receiving waters. Note that the discharge must meet the requirements of the *Environment Protection (Water Quality Policy) 2003* or an exemption must be sought and granted.

The following approaches to remediation of acid sulfate soil material are considered for the Barker Inlet and Gillman physiography, the details of which are contained in the manual *Coastal Acid Sulfate Soil Management Guidelines, Barker Inlet SA Version 1.2* (Thomas *et al* 2003):

- Re-flooding:
  - seawater re-flooding (neutralisation)
  - water table management (containment and neutralisation)
  - freshwater wetlands (neutralisation and dilution).

As noted above, the discharge must meet the requirements of the Environment Protection (Water Quality Policy) 2003 or an exemption must be obtained.

- Bioremediation (neutralisation and containment)
- Lime slotting (chemical neutralisation)
- Leaching/aging (requires chemical neutralisation).

## Environmental management plan

If excavation or disturbance of acid sulfate soil material is unavoidable, the proponent is required to prepare an Environmental Management Plan (EMP) to the satisfaction of the EPA in accordance with the *EPA Guideline: Environmental management of on-site remediation* <[www.epa.sa.gov.au/pdfs/guide\\_remediation.pdf](http://www.epa.sa.gov.au/pdfs/guide_remediation.pdf)>.

The EMP should be a document that describes how the proponent will achieve acceptable environmental outcomes for the protection of soils, surface water and groundwater, the receiving environment and the community.

The EMP should clearly:

- summarise the environmental condition of the site and adjacent areas and potential impacts of the work to be conducted
- summarise the proposed development and works
- describe the proposed acid sulfate soil management measures for all phases of construction and operation
- outline a monitoring program for soils, surface water, groundwater and air during construction and operations, including parameters, monitoring locations, monitoring frequency, laboratory analysis and reporting protocols
- summarise new technologies that are proposed and, if applicable, include results of trials demonstrating effectiveness of the procedures

- describe contingency procedures to deal with unexpected events and failure of management measures and Remedial Management Plan (RMP).

The suitability of management measures will depend on the nature of the receiving environment and the characteristics of the acid sulfate soil. Management costs for acid sulfate soils may be reduced where it can be demonstrated that the acid sulfate soils are self-neutralising or there are other mitigating factors to prevent acid discharge to the environment.

It is recommended that prior to submission of the EMP the proponent should contact the EPA to discuss the contents of the plan and identify other information that may be required.

## References

- Ahern CR, Hey KM, Watling KM & Eldershaw VJ (eds) 2000, *Acid Sulfate Soils: Environmental Issues, Assessment and Management*, Technical Papers, Brisbane, 20–22 June 2000, Department of Natural Resources, Indooroopilly, Queensland, Australia.
- Ahern CR, McElnea AE & Sullivan LA 2004, 'Acid Sulfate Soils Laboratory Methods Guidelines', in *Queensland Acid Sulfate Soils Manual 2004*, Department of Natural Resources, Mines and Energy, Indooroopilly, Queensland, Australia.
- Dear SE, Moore NG, Dobos SK, Watling KM & Ahern CR 2002, 'Soil Management Guidelines', in *Queensland Acid Sulfate Soil Technical Manual version 3.8*, Department of Natural Resources and Mines, Indooroopilly, Queensland, Australia.
- Fitzpatrick RW, Powell B & Marvanek S 2006, 'Coastal Acid Sulfate Soils: National Atlas and Future Scenarios', *Coast To Coast 2006: Australia's National Coastal Conference*, May 22–25 2006, Melbourne Exhibition Centre, Melbourne, viewed 23 October 2007, <[www.vcc.vic.gov.au/coasttocoast2006.htm](http://www.vcc.vic.gov.au/coasttocoast2006.htm)>
- Isbell RF 1996, *The Australian soil classification*, CSIRO Publishing, Melbourne.
- Merry RH, Fitzpatrick RW, Barnett EJ, Davies PJ, Fotheringham DG, Thomas BP & Hicks WS 2003, *South Australian Inventory of Acid Sulfate Soil Risk (Atlas)*, Final project report to Coastal Acid Sulfate Soils Program (CASSP) March 2003, viewed 23 October 2007, <[www.clw.csiro.au/staff/FitzpatrickR/publications.html](http://www.clw.csiro.au/staff/FitzpatrickR/publications.html)>.
- National Environment Protection Council, 1999, *National Environment Protection (Assessment of Site Contamination) Measure 1999*, National Environment Protection Council Service Corporation, Adelaide, South Australia, Australia
- National Working Party on Acid Sulfate Soils 2000, *National Strategy for the Management of Acid Sulfate Soils*, NSW Agriculture, Wollongbar, New South Wales, Australia.
- Soil Survey Staff 2003, *Keys to soil taxonomy*, 9th edition, United States Department of Agriculture, Soil Conservation Service, Blacksburg, viewed 23 October 2007, <[soils.usda.gov/technical/classification/tax\\_keys/](http://soils.usda.gov/technical/classification/tax_keys/)>.
- Standards Australia 2005, *AS 4482.1-2005 Guide to the investigation and sampling of sites with potentially contaminated soil Part 1: Non-volatile and semi-volatile compounds*, Standards Australia, Sydney, New South Wales, viewed 23 October 2007, <[www.standards.org.au](http://www.standards.org.au)>.

Thomas BP, Fitzpatrick RW, Merry RH & Hicks WS 2003, *Coastal Acid Sulfate Soil Management Guidelines, Barker Inlet, SA*, Coastal Acid Sulfate Soil Management Guidelines, Barker Inlet SA (Version 1.2), CSIRO Land and Water, Urrbrae, South Australia, viewed 23 October 2007, <[www.clw.csiro.au/staff/FitzpatrickR/publications.html](http://www.clw.csiro.au/staff/FitzpatrickR/publications.html)>, <[www.clw.csiro.au/staff/FitzpatrickR/barker\\_inlet\\_reports/final\\_app1\\_coastal\\_ASS\\_tech\\_manual\\_v1.2.pdf](http://www.clw.csiro.au/staff/FitzpatrickR/barker_inlet_reports/final_app1_coastal_ASS_tech_manual_v1.2.pdf)>.

Victorian EPA, 1999, *EPA Bulletin - Acid Sulfate Soil and Rock* viewed 23 October 2007, <[epanote2.epa.vic.gov.au/EPA/Publications.nsf/2f1c2625731746aa4a256ce90001cbb5/086f970417c795824a2567fc001e2eb5/\\$FILE/655.pdf](http://epanote2.epa.vic.gov.au/EPA/Publications.nsf/2f1c2625731746aa4a256ce90001cbb5/086f970417c795824a2567fc001e2eb5/$FILE/655.pdf)>.

## CURRENCY OF THIS GUIDELINE

This guideline offers advice to assist with compliance with the general environmental duty and specific environmental policies. It is subject to amendment and persons relying on the information should check with the EPA to ensure that it is current at any given time.

## FURTHER INFORMATION

### *Legislation*

Legislation may be viewed on the internet at: <[www.legislation.sa.gov.au](http://www.legislation.sa.gov.au)>

Copies of legislation are available for purchase from:

Service SA Government Legislation Outlet	Telephone:	13 23 24
101 Grenfell Street	Facsimile:	(08) 8204 1909
Adelaide SA 5000	Internet:	< <a href="http://shop.service.sa.gov.au">shop.service.sa.gov.au</a> >

### *For general information please contact:*

Environment Protection Authority	Telephone:	(08) 8204 2004
GPO Box 2607	Facsimile:	(08) 8124 4670
Adelaide SA 5001	Freecall (country):	1800 623 445
	Internet:	< <a href="http://www.epa.sa.gov.au">www.epa.sa.gov.au</a> >
	E-mail:	< <a href="mailto:epainfo@epa.sa.gov.au">epainfo@epa.sa.gov.au</a> >

## APPENDIX A FIELD INDICATORS AND TESTS FOR SOIL AND WATER

Field morphological indicators and testing for acid sulfate soil materials are described below (Victorian EPA, 1999).

### Field indicators for *actual* acid sulfate soil materials and conditions

- Unusually clear or milky blue-green drainage water within or flowing from the area. (Aluminium released by the acid sulfate soils acts as a flocculating agent.)
- Extensive iron stains on any drain or pond surfaces, or iron-stained water and ochre deposits.
- Water of pH <4 in adjacent streams, drains, groundwater or ponding on the surface.
- Soil pH <3.5–4 (Isbell 1996; Acid Sulfate Soils Manual 1998).
- Jarosite containing horizons (a pale yellow mineral deposit which can precipitate as pore fillings and coatings on fissures) or iron oxide mottling in auger holes or recently dug surfaces. With a fluctuating water table, jarosite may be found along cracks and root channels in the soil jarosite is not always found in actual acid sulfate soils.
- Jarosite present in surface encrustations or in any material dredged or excavated and left exposed.
- Corrosion of concrete and/or steel structures.
- Dominance of mangroves, reeds, rushes and other swamp-tolerant vegetation.
- Sulfurous (H<sub>2</sub>S) smell after rain following a dry spell, or when the soils are oxidised or disturbed.

### Field indicators for *potential* acid sulfate soil conditions

- Typically waterlogged, unripe muds (soft, buttery texture, blue grey or dark greenish grey) or estuarine silty sands or sands (mid to dark grey) or bottom sediments of estuaries and tidal lakes (dark grey to black).
- A pH of 6–8.
- Positive peroxide test (Acid Sulfate Soils Manual 1998).
- Offensive odour, predominantly due to 'rotten egg gas' (hydrogen sulfide H<sub>2</sub>S).

## APPENDIX B ANALYTICAL METHODS FOR ACID SULFATE SOIL MATERIALS ASSESSMENT

### Selection of analytical methods

Selection of appropriate assessment, sampling and analytical methods should be based on characterisation of the material in terms of the unconfined (or uniaxial) compressive strength of an intact sample of the material. These estimates can be determined using simple field techniques as follows:

- Soil and sediments geological material that has an unconfined compressive strength less than two megapascals (MPa): that is, an intact sample can be deeply cut with a knife, crumbled with a pick, or flattened or powdered with a hammer. Materials in this category include soil, sediment and very weak rock, which are estimated to behave as soil under field and analytical conditions. Assess using soil field indicators, sampling frequencies, and SPOCAS analysis method for classification.
- Rock geological material that has an unconfined compressive strength greater than 2 MPa: that is, an intact sample can at most be shallowly cut or scratched with a knife, indented deeply with a pick, or shattered into many small fragments with a hammer. Materials in this category include weak through to very strong rocks that are estimated to behave as rock materials under field and analytical conditions. Assess using rock field indicators, sampling frequencies, and NAPP/NAG analysis methods for classification.

Methods for analysing soil and rock samples to assess acid sulfate generation potential are given in Ahearn, McElnea and Sullivan (2004) and include:

#### A ACTUAL ACIDITY METHOD

KCL PH ( $PH_{KCL}$ ) & TITRATABLE ACTUAL ACIDITY ( $TAA_{KCL}$ ) (Method codes 23A & 23F)

#### B POTENTIAL ACIDITY METHODS

PEROXIDE PH ( $PH_{OX}$ ), TITRATABLE PEROXIDE ACIDITY (TPA) & EXCESS ACID NEUTRALISING CAPACITY ( $ANC_E$ ) (Method codes 23b, 23g & 23q)

TITRATABLE SULFIDIC ACIDITY (TSA) (METHOD CODE 23H)

#### C SULFUR METHODS—FOR ESTIMATING POTENTIAL ACIDITY B5-1

TOTAL & pseudo-total SULFUR ( $S_T$ ) (METHOD CODE 20A)

CHROMIUM REDUCIBLE SULFUR ( $S_{CR}$ ) (METHOD Code 22B)

SULFUR—PEROXIDE OXIDATION METHOD (Method code 23d)

#### D SULFUR—VARIOUS EXTRACTION TECHNIQUES

SULFUR 1 M KCL EXTRACTION ( $S_{KCL}$ )—METHOD CODE 23C 1

SULFUR 4 M HCL EXTRACTION ( $S_{HCL}$ )—METHOD CODE 20B B9-1

PEROXIDE RESIDUEL ACID SOLUBLE SULFUR ( $S_{RAS}$ ) (METHOD CODE 23R)

**E SULFUR—PARAMETERS CALCULATED FROM OTHER SULFUR ANALYSES**

## CALCULATED SULFUR PARAMETERS

Total Oxidisable Sulfur ( $S_{\text{tos}}$ )—Method Code 20CPeroxide Oxidisable Sulfur ( $S_{\text{pos}}$ )—Method Code 23ENet Acid Soluble Sulfur ( $S_{\text{nas}}$ )—Method Code 20J

## OVERVIEW OF THE COMPLETE SPOCAS METHOD

Outline of SPOCAS for laboratory use—Method Code 23

**F ACID NEUTRALISING CAPACITY, CARBONATE AND ALKALI CATION METHODS**

METHOD CODES 19A1, 19A2, 19C1, 23X, 23U, 19F1, 19G1)

## APPENDIX C CRITERIA FOR ACID SULFATE SOIL MATERIAL

Separate criteria have been developed for soil and rock which, if exceeded, classify the material as acid sulfate soil material. They are included in the following tables.

### Soil Criteria

Soil or sediment texture	Criteria	
	Sulfur trail % oxidisable sulfur (oven dry basis)	Acid trail mol H <sup>+</sup> /tonne (oven dry basis)
Sands to loamy sands	0.03	18
Sandy loams to light clays	0.06	36
Medium to heavy clays and silty clays	0.1	62

### Notes

- 1 Soil or sediment texture is defined in the *Australian Soil and Land Survey Field Handbook* by McDonald RC, Isbell RF, Speight JG, Walker J & Hopkins MS (1990), 2nd ed.
- 2 Sulfur trail and acid trail are to be determined by the method given in:  
McElnea AE and Sullivan LA, Acid Sulfate Soils Laboratory Methods Guidelines, in *Queensland Acid Sulfate Soils Manual 2004*, Department of Natural Resources, Mines and Energy, Indooroopilly, Queensland, Australia.

### Rock Criteria

Final Net Acid Generation pH	Net Acid Generation Value (kgH <sub>2</sub> SO <sub>4</sub> /tonne)	Net Acid Producing Potential (kg H <sub>2</sub> SO <sub>4</sub> /tonne)
<4.5	>5	Positive

### Notes

- 1 Final net acid generation (NAG) pH and NAG value are to be determined by the method given in Miller S, Robertson A & Donahue T 1997, 'Advances in Acid Drainage Prediction using the Net Acid Generation (NAG) Test', 4<sup>th</sup> *International Conference on Acid Rock Drainage*, Vancouver, BC.
- 2 Net acid producing potential (NAPP) is to be determined by Chemical Method 3.2.3 Neutralization Potential and Chemical Method 3.2.4 Total Sulfur in: Sobek A.A, Schuller WA, Freeman JR & Smith RM 1978, *Field and Laboratory Methods Applicable to Overburdens and Minesoils*, USEPA Publication EPA-600/2-78-054, and Miller *et al* 1997 (as in Note 1).